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Kumar et al.

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(54) **SPINAL FIXATION SYSTEM**

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Related U.S. Application Data

(60) Continuation of application No. 13/523,032, filed on Aug. 14, 2012, now Pat. No. 8,551,146, which is a continuation of application No. 12/582,010, filed on Oct. 20, 2009, now Pat. No. 8,221,470, which is a division of application No. 11/510,685, filed on Aug. 25, 2006, now abandoned, which is a continuation of application No. 10/647,587, filed on Aug. 26, 2003, now Pat. No. 7,118,571, which is a continuation of application No. 09/915,572, filed on Jul. 27, 2001, now Pat. No. 6,610,063.

(60) Provisional application No. 60/221,518, filed on Jul. 28, 2000.

(51) **Int. Cl.**
A61B 17/70 (2006.01)
A61B 17/88 (2006.01)

(52) **U.S. Cl.**
CPC ***A61B 17/7032*** (2013.01); ***A61B 17/7038*** (2013.01); *A61B 17/8875* (2013.01); ***A61B 17/7056*** (2013.01); ***A61B 17/7041*** (2013.01); *A61B 17/7076* (2013.01); *A61B 17/7049* (2013.01)
USPC **606/267**; 606/272

(58) **Field of Classification Search**
USPC 606/324, 60, 246–279
See application file for complete search history.

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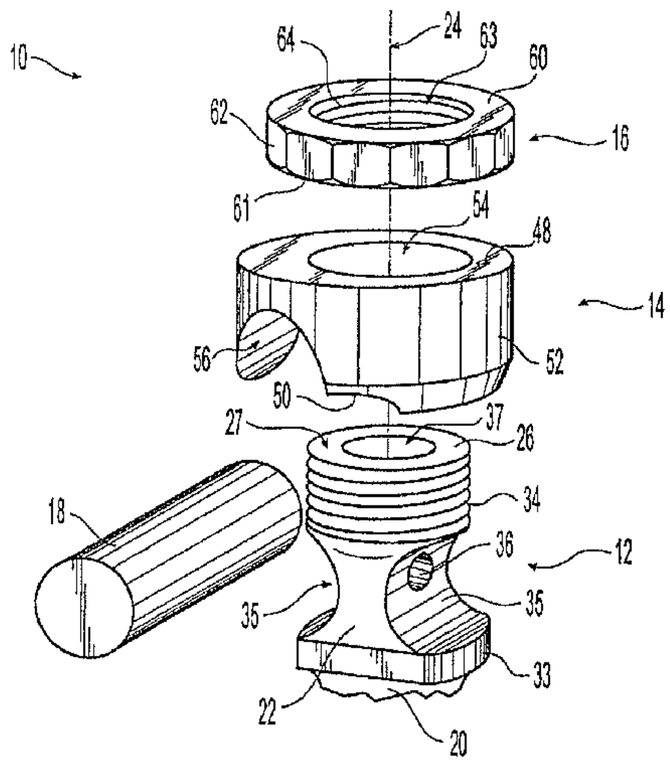
(57) **ABSTRACT**

A fastener assembly for a spinal fixation system that is particularly useful in treatment of pediatric and small-statured patients includes a fastener, an attachment member, and a locking member. The fastener has a lower portion for contacting a bone and an upper portion integral with the lower portion. The upper portion has two open channels. Each channel is configured and dimensioned to receive a portion of a longitudinal or connecting member along its circumference. The attachment member is positionable on the fastener and at least partially covers the channel that receives the longitudinal or connecting member. The locking member is operatively associated with the upper portion of the fastener and secures the attachment member and the longitudinal or connecting member to the fastener.

23 Claims, 7 Drawing Sheets



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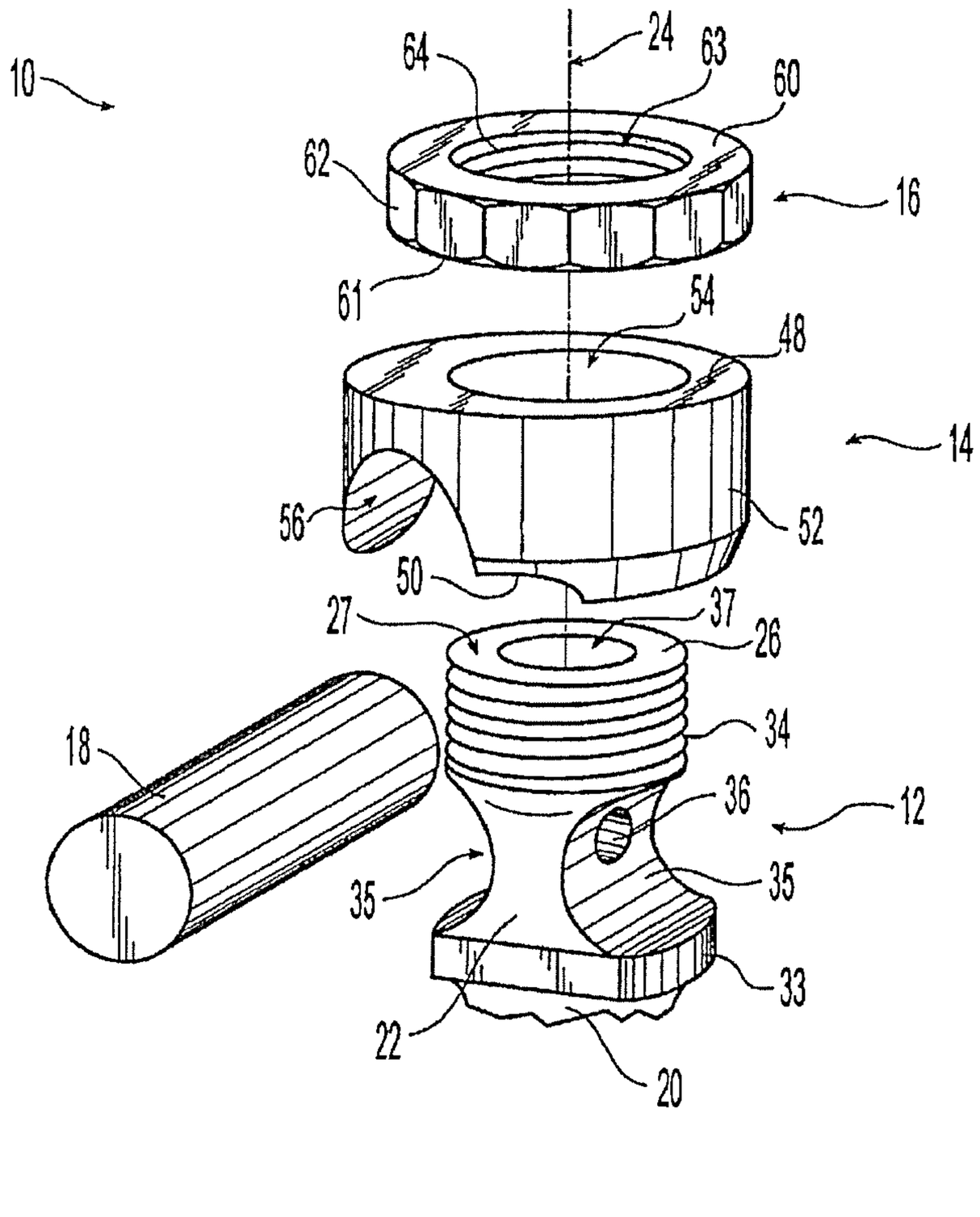
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Fig. 1

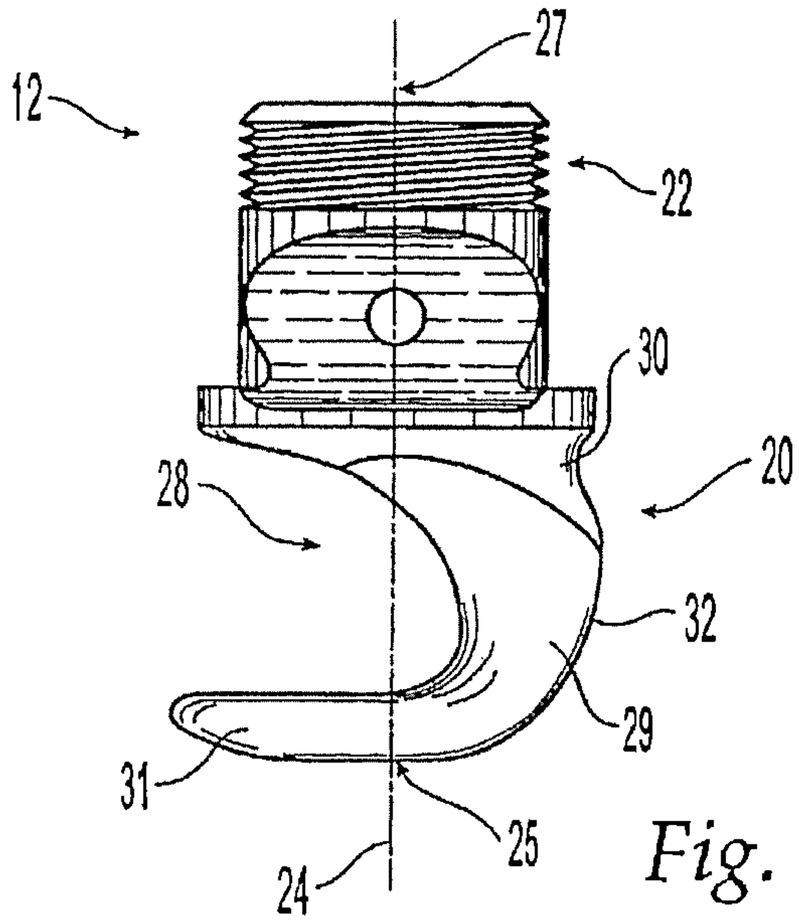

Fig. 2

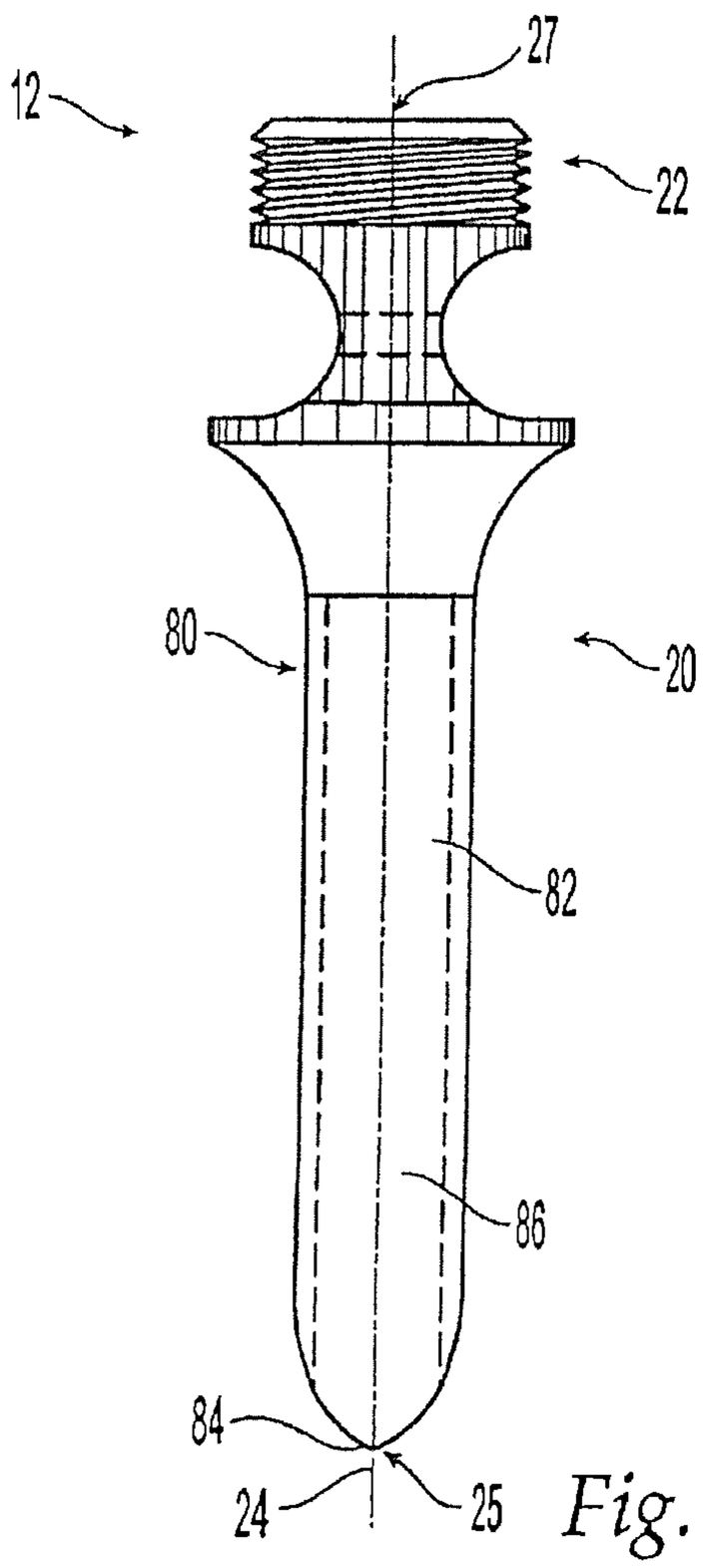

Fig. 3

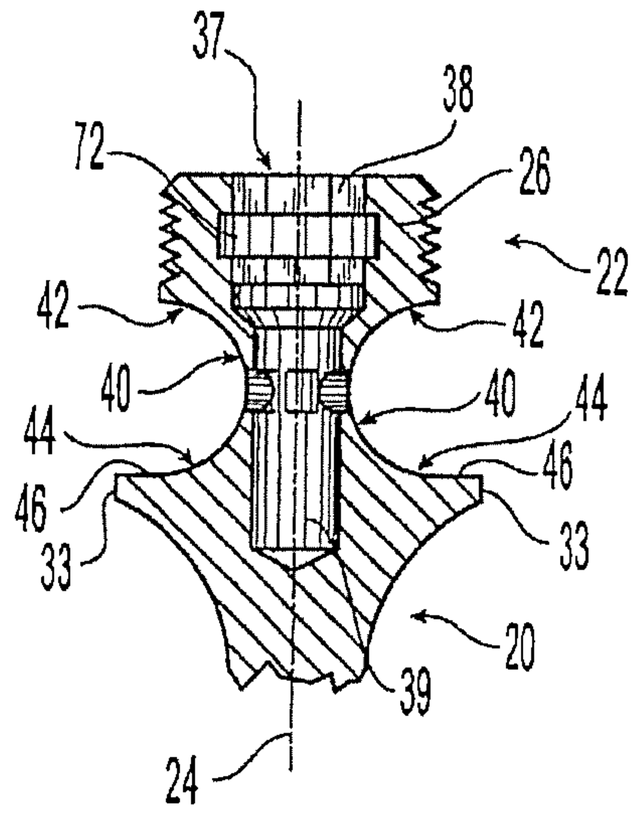

Fig. 4

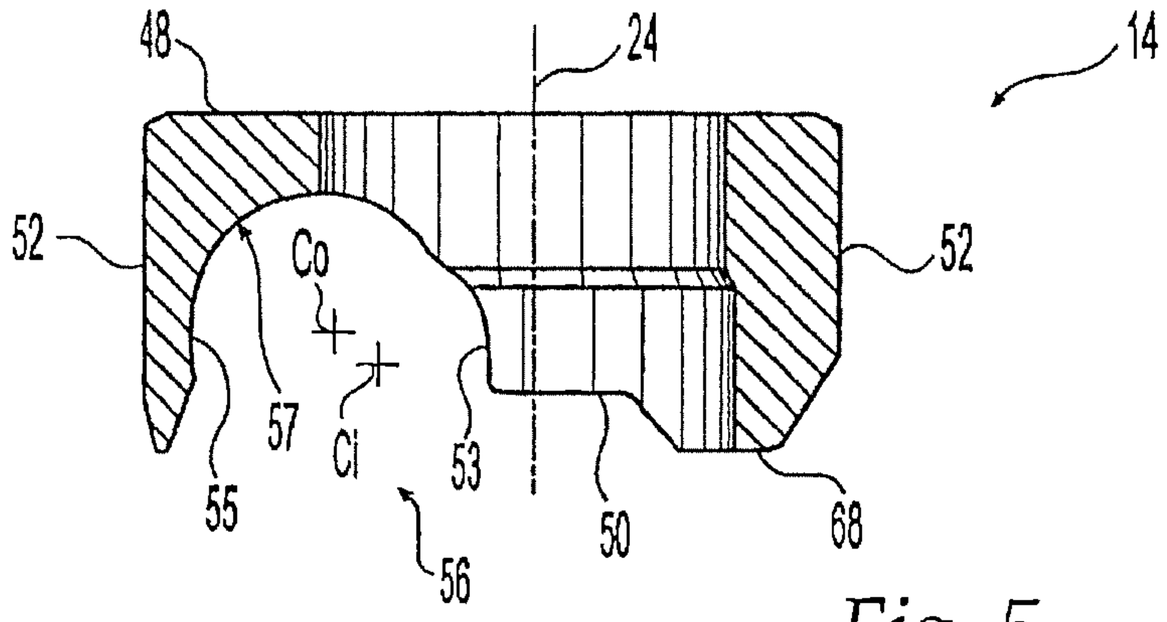

Fig. 5

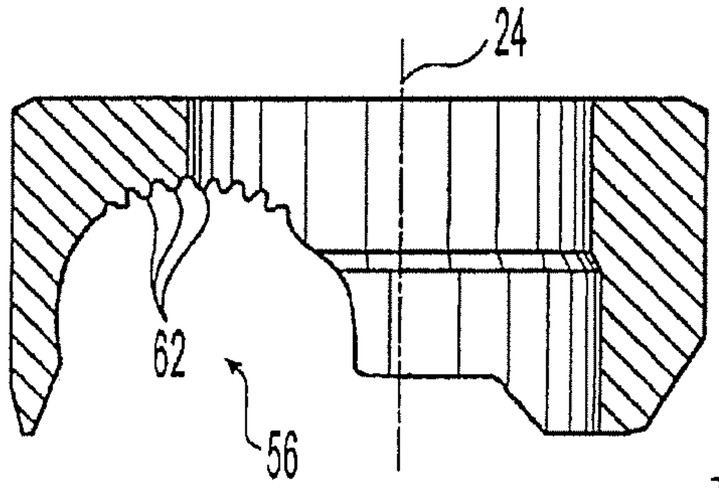

Fig. 6

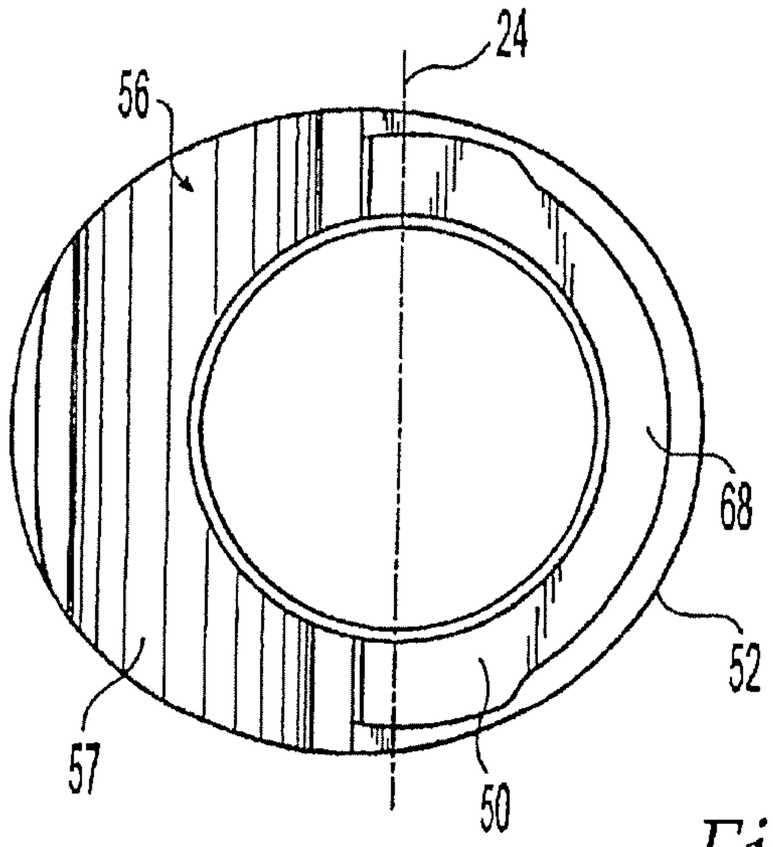

Fig. 7

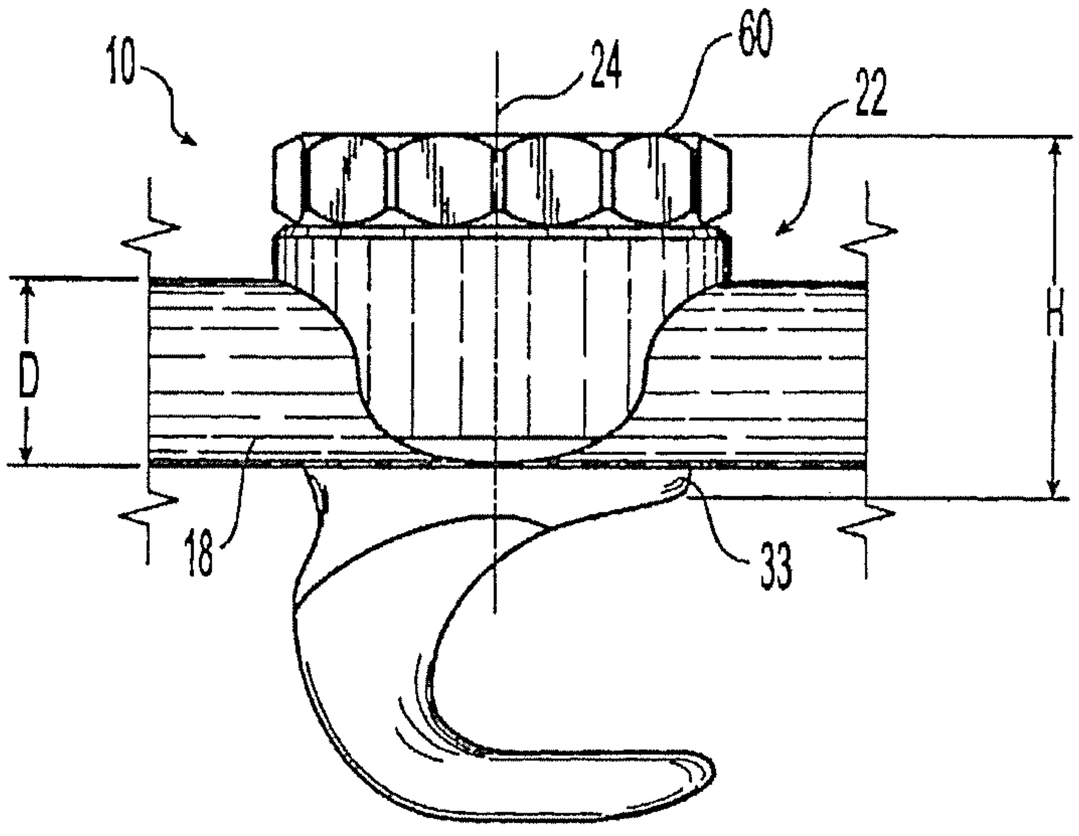

Fig. 8

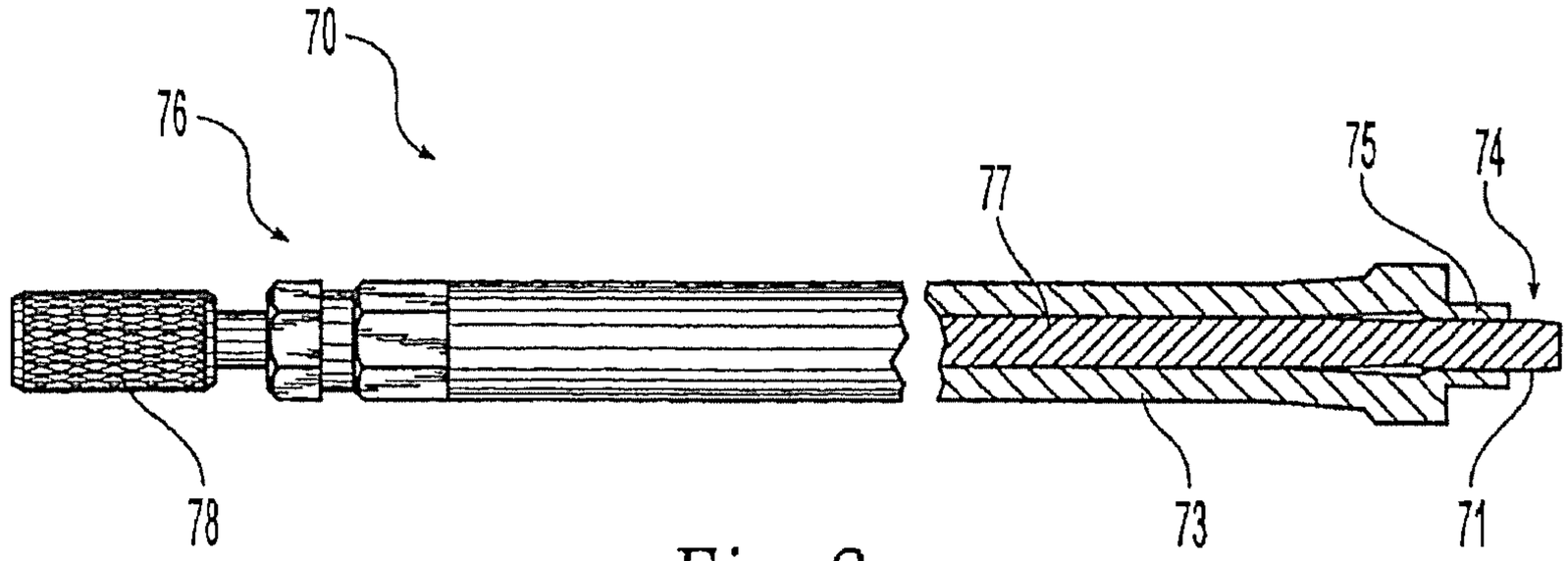

Fig. 9

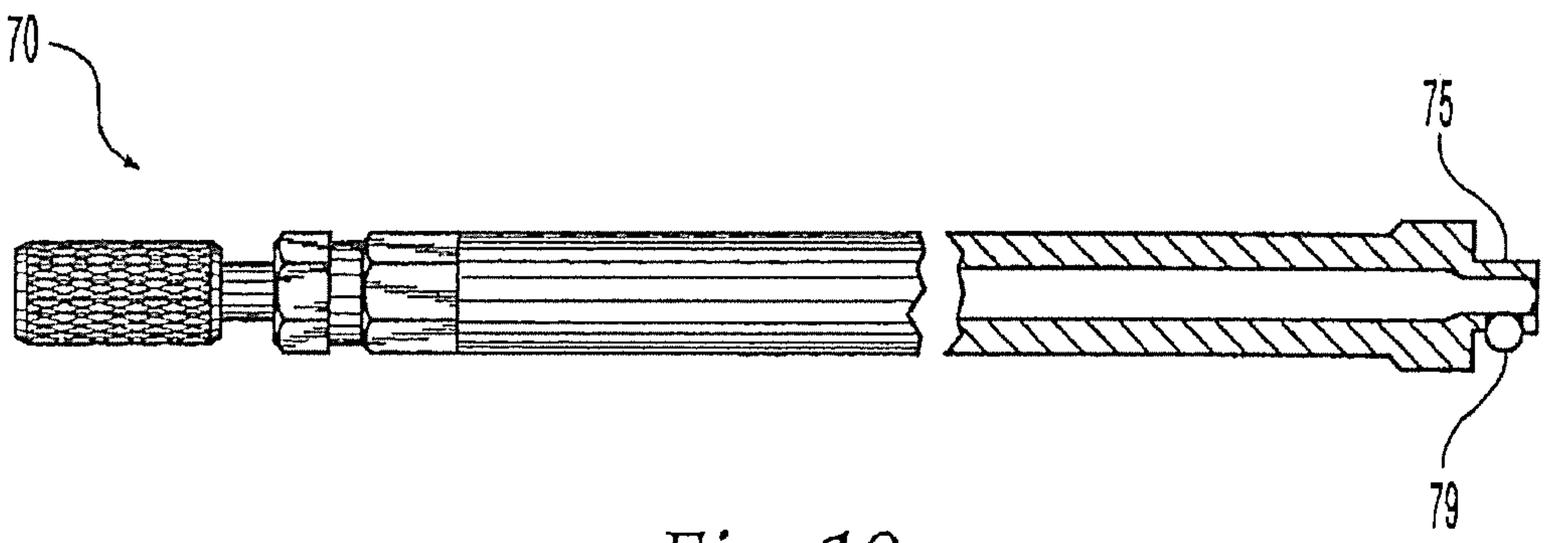

Fig. 10

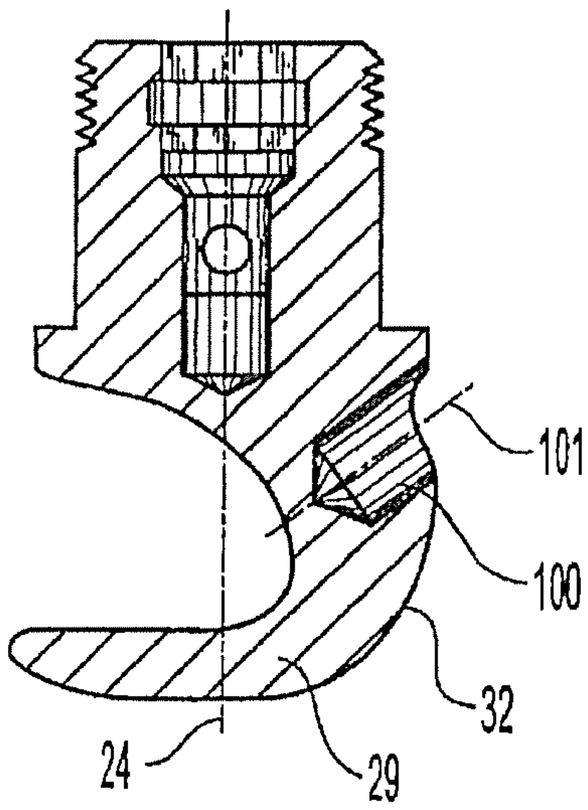

Fig. 11

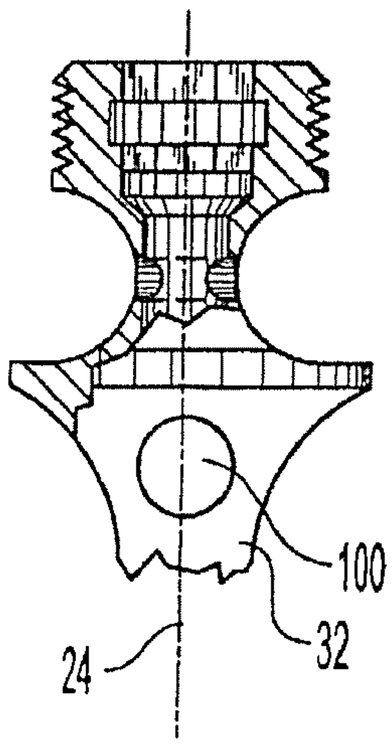

Fig. 12

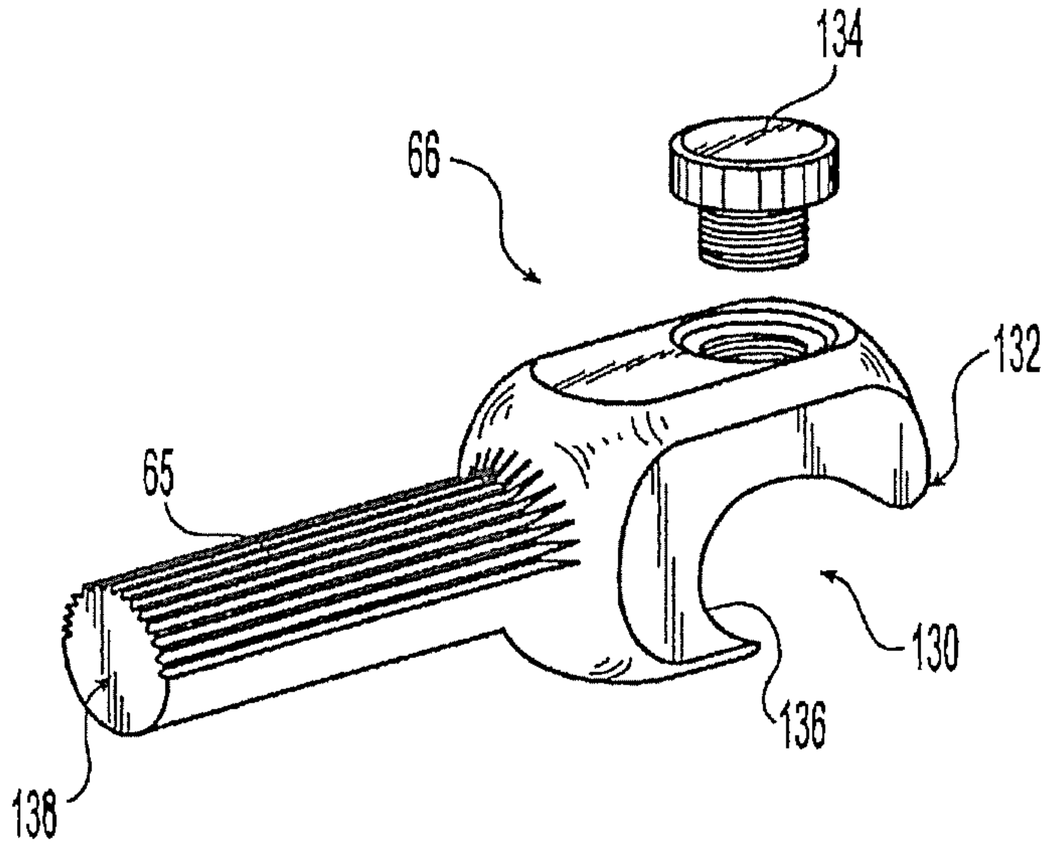

Fig. 13

SPINAL FIXATION SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation of pending U.S. application Ser. No. 13/523,032, filed Jun. 14, 2012, which is a continuation of U.S. application Ser. No. 12/582,010, filed Oct. 20, 2009, now U.S. Pat. No. 8,221,470, which is a divisional of U.S. application Ser. No. 11/510,685, filed Aug. 25, 2006, now abandoned, which is a continuation of U.S. application Ser. No. 10/647,587, filed Aug. 26, 2003, now U.S. Pat. No. 7,118,571, which is a continuation of U.S. application Ser. No. 09/915,572, filed Jul. 27, 2001, now U.S. Pat. No. 6,610,063, which claims the benefit under 35 U.S.C. §119(e) of U.S. Provisional Application No. 60/221,518, filed Jul. 28, 2000, the entire contents of each are expressly incorporated herein by reference thereto.

TECHNICAL FIELD

The invention relates to a spinal fixation system, and in particular to a fastener assembly for securing a longitudinal support along a spinal column.

BACKGROUND

Stabilization of the spine is often required following trauma, tumor, or degenerative pathologies. Each region of the spine presents unique clinical challenges as several vital neural and vascular structures including the vertebral arteries, nerve roots, and spinal cord must be avoided during surgery. The anatomy of pediatric and small-statured patients presents additional challenges that makes assisting such patients even more difficult. For example, because these patients are small in stature, lower profile systems are required. Also, it may be required to add fastener assemblies to an already assembled system, especially in pediatric patients. At the same time, it is desirous to keep inventory at a minimum and have an assembly that requires as few components as possible.

Current methods of spinal fixation are not particularly well-suited for smaller statured patients. U.S. Pat. No. 5,737,685 to Halm et al. discloses a bone screw that has a threaded shaft and a fork head. The fork head has two legs which define a single groove that opens in the vertical direction for receiving a corrective pin. The upper end of the fork head has an outside thread and a head nut is screwed onto the outer thread. The head nut has inner threads which a fastening screw is screwed to press onto the corrective pin. Because the groove opens in a vertical direction it is difficult to add additional screws to an already installed fixation system.

U.S. Pat. No. 5,530,441 to Sherman et al. discloses an attachment plate configured for use with a spinal fixation element that has a posteriorly projecting central post. The attachment plate is generally L-shaped with an eyebolt engaging portion and a fixation element clamping portion. The fixation element has grooves in the lateral surfaces of the central post and one lateral surface of the post contacts the spinal rod when the rod extends through an aperture of an eyebolt assembly. A flange extends from the attachment plate and is configured to engage the opposite lateral surface of the post and the attachment plate includes a camming segment to provide a clamping force component directed toward the flange to clamp the spinal rod to the fixation element post when a nut is threaded onto the eyebolt threaded post. The attachment plate has a slot in the eyebolt engaging portion for receiving the posteriorly projecting threaded post of the eyebolt body. Because the eyebolt must be pre-assembled onto the spinal rod, it is difficult to add additional fixation elements to an already installed system.

U.S. Pat. No. 4,653,481 to Howland et al. discloses a spinal support system that includes a plurality of screw clamp assemblies. Each screw clamp assembly has a threaded end for placement into the vertebra and a saddle assembly removably attached to the screw formed of upper and lower halves. Each of the upper and lower halves of the saddle assembly are provided with at least one pair of mating grooves for accepting a spinal rod. All embodiments shown and described in the Howland '481 patent have a two-part saddle assembly that is removable from the screw clamp shaft member.

In view of the foregoing, a need exists for an improved fixation apparatus for stabilizing the spine that can be assembled to an already installed fixation system and that has minimal components.

SUMMARY

The invention relates to a fastener assembly for a spinal fixation system. The fastener assembly includes a fastener, an attachment member, and a locking member. The fastener has a lower portion for contacting a bone and a upper portion integral with the lower portion and having two open channels. Each channel is configured and dimensioned for receiving a portion of the longitudinal member along its circumference. The attachment member is positionable on the fastener and at least partially covers the channel that receives the longitudinal member. The attachment member is configured and dimensioned for receiving another portion of the longitudinal member along its circumference. The locking member is operatively associated with the upper portion of the fastener and secures the attachment member and longitudinal member to the fastener.

The fastener can be a hook or a screw with the lower portion having a threaded end for engaging a vertebra. If the fastener is a hook, the hook can be provided with an arcuate portion and a flat portion for facilitating implantation. The arcuate portion can have a dimple on a posterior surface to further facilitate implantation. In one embodiment, the locking member is a nut and the upper portion of the fastener has a shaft with external threads to accept the locking member.

The two channels of the fastener are preferably disposed on opposite sides of a central plane of the fastener with the two channels extending orthogonally with respect to the fastener longitudinal axis and equidistant from the proximal end of the fastener. A bore can be positioned transversely to the longitudinal axis and between the two channels.

In an exemplary embodiment, the attachment member includes a cylinder having upper, lower, and side surfaces with a bore extending through the upper and lower surfaces and defining a longitudinal axis lying in a central plane; a slot extending through the cylinder offset from the central plane and parallel with the central plane; and a protrusion extending from the bottom surface on an opposite side of the central plane from the slot. The channels can define a seat for accepting the protrusion of the attachment member. The slot can be provided with serrations along the inner surface. The slot can also have an eccentric cross-sectional shape with a geometry substantially conforming to a diameter of the longitudinal member.

The fastener can have a cavity extending longitudinally from the distal end for receiving a manipulation device. This manipulation device includes a ball detent mechanism and a groove extending transversely to the cavity and around its circumference for receiving the ball detent mechanism. Alter-

natively, the manipulation device has a threaded end and the cavity of the fastener is cylindrical and includes threads along the interior.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded perspective view of a fastener assembly according to the invention;

FIG. **2** is a side view of one embodiment of a fastener for the fastener assembly of FIG. **1**;

FIG. **3** is a front view of another embodiment of a fastener for the fastener assembly of FIG. **1**;

FIG. **4** is a cross-sectional view of the upper portion of a fastener of the fastener assembly of FIG. **1** taken along a central plane;

FIG. **5** is a cross-sectional view of the attachment member of the fastener assembly of FIG. **1** taken along a central plane;

FIG. **6** is a cross-sectional view of another embodiment of the attachment member of the fastener assembly of FIG. **1** taken along a central plane;

FIG. **7** is a bottom view of the attachment member of FIG. **5**;

FIG. **8** is a side view of the fastener assembly of FIG. **1** showing the fastener as a hook;

FIG. **9** is a front view of one embodiment of a manipulation device according to the invention;

FIG. **10** is a front view of another embodiment of a manipulation device according to the invention;

FIG. **11** is a cross-sectional view of the fastener of FIG. **2** taken along a central plane;

FIG. **12** is a back view of the fastener of FIG. **2**; and

FIG. **13** is a perspective view of a transverse bar according to the invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Referring to FIG. **1**, the fastener assembly **10** according to the invention generally includes a fastener **12**, an attachment member **14** positionable on fastener **12** and a locking member **16** securable upon fastener **12**. The fastener assembly **10** may be used in a spinal fixation system to secure a longitudinal member **18**, such as a rod, along a spinal column. Fastener **12** has a lower portion **20** for engaging a vertebra, and an upper portion **22** integral with lower portion **20** for securing the longitudinal member **18** to fastener **12**.

Referring to FIGS. **2** and **3**, lower portion **20** of fastener **12** preferably comprises a hook or pedicle screw, and has a longitudinal central axis **24** extending from a proximal end **25** to a distal end **27** and lying in a central plane. In FIG. **2**, lower portion **20** comprises a hook **28** and includes a curved hook body **29** with a first end **30** connected to the upper portion **22** and a second free end **31**. Hook body **29** is convex on its posterior side **32**. Free end **31** runs essentially perpendicular to the central axis **24** and is adapted to the spinal geometry. As can be seen in FIG. **3**, in another embodiment, lower portion **20** comprises a pedicle screw **80**. Pedicle screw **80** comprises a screw body **82** with a screw point **84** and a thread **86** on the outside of the screw body **82** for engaging the vertebra. Preferably, the screw **80** is self-tapping and includes a blunt screw point **84**.

Referring to FIGS. **1-4**, the upper portion **22** is generally in the form of a shaft **26** extending along central axis **24** and accepts the attachment member **14** and the locking member **16**. Upper portion **22** has a shoulder **33** at a first end adjacent the lower portion **20** and an external threaded portion **34** at the distal end **27** of fastener **12**. At least two channels **35** traverse the shaft **26**, and the channels **35** are preferably disposed on opposite sides of the central plane. The channels **35** extend orthogonal with respect to the central axis **24** and are preferably equidistant from the distal end **27**. Preferably a bore **36** runs between the channels **35** transverse to the central axis **24** to facilitate the machining of a cavity **37** in the distal end **27** of fastener **12**. The external threading **34** engages internal threading of locking member **16** so that locking member **16** is tightenable on the shaft **26**.

Each channel **35** is configured and dimensioned for receiving at least a portion of the longitudinal member **18**. In a preferred embodiment, longitudinal member **18** is an elongate rigid rod having a circular cross-section taken in a plane extending perpendicular to the longitudinal central axis of the rod. As best seen in FIG. **4**, in accordance with this embodiment, channels **35** preferably have an arcuate section **40** centrally disposed between upper **42** and lower **44** legs opening substantially laterally with respect to the central axis **24** of shaft **26**. Arcuate section **40** has a diameter substantially conforming to the diameter of the rod. Preferably, the lower leg **44** extends further radially outward from the central axis **24** than upper leg **42** and defines a seat **46** for supporting a portion of the attachment member **14**. Numerous other embodiments are envisioned in which the longitudinal member may have varied cross-sections, such as a rectangular bar or elliptical wire. Accordingly, channels **35** can have numerous shapes corresponding to the particular geometry of the longitudinal member used.

Referring again to FIG. **1**, the attachment member **14** preferably has a generally cylindrical shape having upper **48**, lower **50** and side **52** surfaces with a bore **54** extending through the upper **48** and lower **50** surfaces along central axis **24**. Bore **54** extends through the attachment member **14** so that the attachment member **14** can be inserted over the external threading **34** to be positionable on the upper portion **22** of fastener **12**. A slot **56** extends transversely through the attachment member **14** and is orthogonal to central axis **24** and offset from the central axis **24**. Slot **56** is configured and dimensioned for receiving the longitudinal member **18** and locatable adjacent either of the channels **35** for securing the longitudinal member **18** to the upper portion **22** of fastener **12**. When the longitudinal member **18** is inserted in channel **35** and attachment member **14** is assembled upon the upper portion **22**, locking member **16** tightens attachment member **14** to secure the longitudinal member **18** in slot **56** and against one of the channels **35**.

Locking member **16** substantially resembles a nut and has a generally disc-like shape with top **60**, bottom **61** and side **62** surfaces with a hole **63** extending centrally through the top **60** and bottom **61** surfaces. The hole **63** is provided with internal threading **64** which mates with external threading **34** provided on shaft **26** of upper portion **22**. As such, locking member **16** is tightenable on the shaft **26** and the bottom surface **61** contacts the upper surface **48** of the attachment member **14** to force the attachment member **14** downward toward the lower portion **20** as locking member **16** is tightened. Side surface **62** is preferably provided with a polygonal geometric configuration comprising twelve points to facilitate tightening.

The slot **56** has a generally cylindrical cross-section and has a geometry substantially conforming to the diameter of the longitudinal member **18**. Preferably, slot **56** has an eccentrically shaped cross-section. Referring to FIG. **5**, slot **56** comprises multiple circular sections having centers offset with respect to one another to define an inner surface **57** towards the central axis **24** connecting inner section **53** with outer section **55**. Inner and outer sections **53**, **55** preferably

have circular geometries. Inner section **53** has a center of curvature C, offset inward towards central axis **24** with respect to a center of curvature C_o of outer section **55**. The eccentric shape of inner surface **57** is useful to allow the camming of longitudinal member **18** towards the channels **35** when the attachment member **14** is tightened onto upper portion **22** as inner section **53** allows for movement of the longitudinal member axially inward to forcibly engaging the longitudinal member **18** with either of the channels **35**. As can be seen in FIG. **6**, in one embodiment of attachment member **14**, the slot **56** includes serrations **62** along inner surface **57** for engaging corresponding ridges **65** on a ridged longitudinal member, such as transverse bar **66** (FIG. **13**). In this way, the ridged longitudinal member is less likely to rotate relative to fastener **12** when the attachment member **14** is secured by locking member **16**.

Referring to FIGS. **5-7**, a protrusion **68** extends from lower surface **50** on an opposite side of the attachment member **14** from slot **56**. Protrusion **68** preferably extends generally perpendicular from lower surface **50** and is spaced radially inward from the side surface **52**. Also preferably, protrusion **68** runs arcuately along a portion of lower surface **50** opposite slot **56**. As such, when attachment member **14** is assembled upon the upper portion **22** of fastener **12**, the protrusion **68** preferably engages seat **46** for preventing the attachment member **14** from tilting when the attachment member **14** is tightened by locking member **16**.

As shown in FIG. **8**, upper portion **22** of fastener assembly **10** has a height H measured from the base of shoulder **33** to the top surface **60** of locking member **16**. Preferably height H is as minimal as possible and only slightly greater than the diameter of longitudinal member **18**. Preferably height H is less than 10.0 mm. Also, preferably the ratio of longitudinal member diameter D to height H is greater than 0.50 so that the upper portion **22** has only a slightly higher profile than the longitudinal member **18**. A notable advantage of maintaining such a low height H, or low profile, is that such a fastener assembly **10** is especially well suited for use in pediatric and small-statured patients.

Referring again to FIG. **4**, fastener **12** consists of a cavity **37** in distal end **27** opening upward and having a hexagon socket **38** near the distal end and a cylindrical hole **39** running in the direction of longitudinal central axis **24**, for receiving a manipulation device **70** (FIG. **9**) to facilitate the insertion of the fastener **12** into bone. Cylindrical hole **39** is preferably provided with internal threading that continues from the base of hexagon socket **38** in the direction of lower portion **20** for the positive acceptance of manipulation device **70** with corresponding external threading **71** (FIG. **9**). Here, cavity **37** permits a rotationally-stable, releasable connection with manipulation device **70**. Internal threading can be designed with multiple threads to strongly shorten the time required for the connection process. For this embodiment, manipulation device **70**, shown in FIG. **9**, consists of hollow cylindrical sheath **73** that has at its one end **74** lug **75**. From the other end **76** of sheath **73**, a cylindrical pin **77** can be inserted into sheath **73**. Cylindrical pin **77** carries at its one end external threading **71** that, after successful insertion, protrudes beyond end **74** of sheath **73**, and at its other end, grip **78** protrudes from sheath **73** and serves to tighten the connection.

Preferably a generally rectangular groove **72** extends transverse to the hexagon socket **38** and around the circumference of the cavity **37**. As shown in FIG. **10**, another embodiment of the manipulation device **70** is provided with bearings **79** in lug **75** for engaging groove **72**. When manipulation device **70** is introduced into cavity **37** and bearings **79** align with rectangular groove **72**, pin **77** can be pushed through the sheath **73** in manipulation device **70** to press bearings **79** into rectangular groove **72**. This facilitates the transfer of tensile, compressive and rotational forces via manipulation device **70** without the need to have a threaded coupling.

Referring to FIG. **11**, at convex posterior side **32** of hook body **29** a dimple **100** is provided to accept an installation device (not shown). Dimple **100** comprises a cylindrical hole extending along a longitudinal axis **101** at an angle with respect to the central axis **24**. Referring to FIG. **12**, preferably dimple **100** is located centrally with respect to the posterior side **32**. In this way, dimple **100** provides an ideally suited structure for impaction to facilitate the insertion of flat end **31** into the vertebra.

Referring to FIG. **13**, a transverse bar **66** is shown which may be used as a connector or connecting member to secure the longitudinal member **18** to a fastener **12** that is laterally displaced from member **18** to avoid excessively bending member **18**. The transverse bar **66** includes a hook **130** at one end **132**. A set screw **134** extends through the hook **130** and pins the longitudinal member **18** against the inner surface **136** of the hook **130** to secure the longitudinal member **18** to the transverse bar **66**. The second end **138** of the transverse bar **66** is a shaft that has ridges **65** around the circumference that mate with serrations **59** provided in attachment member **14** as described above.

In use, a plurality of fastener assemblies **10** are inserted into the vertebra along the spine with the aid of the manipulation device **70** and the longitudinal member **18** is placed in one of the two channels **35** on each of the fasteners **12**. An attachment member **14** is placed onto each of the fasteners **12** so that the longitudinal member **18** is held in the channel **35** by the slot **56** of attachment member **14**. A locking member **16** is then used to secure the longitudinal member **18** in the channel **35**. Also, a transverse bar **66** can be secured to the longitudinal member **18** to couple the longitudinal member **18** to a laterally positioned fastener **12**. In that case, the hooked end **132** of the transverse bar **66** is held to the longitudinal member **18** by a set screw **134** and the opposite end **138** of the transverse bar **66** is secured to the fastener **12** by an attachment member **14** in the same fashion as described above for the longitudinal member **18**.

Because of the dual-channel structure of the fastener **12**, a surgeon implementing a spinal fixation system may insert the longitudinal member **18** in either channel **35**. Also, because the slot **56** is offset with respect to central axis **24**, the attachment member **14** may be located on either side of fastener **12** and the longitudinal member **18** may be secured to either one of channels **35**. As a result, fastener assembly **10** may be assembled on either side of the spinal column using the identical components. Further, the integral nature of the upper and lower portions **22**, **20** allows for easy assembly to an already installed spinal fixation system. Because the channels **35** open laterally fastener **12** can be anchored to a vertebra and longitudinal member **18** may be laterally received in upper portion **22** and attachment member **14** can be vertically assembled there over to secure the longitudinal member in place, and no preassembly is required.

While it is apparent that the illustrative embodiments of the invention herein disclosed fulfill the objectives stated above, it will be appreciated that numerous modifications and other embodiments may be devised by those skilled in the art. Therefore, it will be understood that the appended claims are intended to cover all such modifications and embodiments which come within the spirit and scope of the invention.

What is claimed:

1. A fastener assembly configured to affix a longitudinal member to a vertebra, the fastener assembly comprising:

a fastener that defines a central axis and includes a lower portion configured to engage the vertebra, and an upper portion that extends up with respect to the lower portion, such that the upper portion is disposed in an upward direction with respect to the lower portion, the upper portion having a channel surface that defines a channel that is configured to receive the longitudinal member, the channel surface including two points that are opposite each other along a direction parallel to the central axis; and

an attachment member positionable on the upper portion, the attachment member including an inner surface that defines a slot, such that the slot cooperates with the channel so as to capture the longitudinal member when the attachment member is positioned on the upper portion, wherein (i) the inner surface defines an outer section having a first center of curvature and an inner concave section having a second center of curvature that is offset inwards toward the central axis with respect to the first center of curvature and (ii) the outer section of the inner surface includes a plurality of serrations configured to mate with a plurality of ridges on the longitudinal member, wherein the inner surface at the outer section is offset with respect to the inner surface at the inner section in the upward direction.

2. The fastener assembly of claim **1**, wherein the inner surface is concave with respect to the slot along at least a portion of both the outer and inner sections.

3. The fastener assembly of claim **1**, wherein the inner section is offset inward with respect to the outer section toward the central axis.

4. The fastener assembly of claim **1**, wherein the upper portion is integral with the lower portion.

5. The fastener assembly of claim **1**, wherein the channel is a first channel, and the upper portion further has a second channel, the first and second channels disposed on opposite sides of the central axis.

6. The fastener assembly of claim **1**, wherein the upper portion includes an external threading, and the fastener assembly further comprises a locking member having internal threading that is configured to mate with the external threading of the upper portion.

7. The fastener assembly of claim **1**, further comprising the longitudinal member, wherein the longitudinal member is a ridged transverse bar configured to secure a second longitudinal member to the vertebra.

8. The fastener assembly of claim **7**, wherein the ridged transverse bar includes a shaft that defines the plurality of ridges.

9. The fastener assembly of claim **8**, wherein the shaft is elongate along a first direction and the plurality of ridges are elongate along the first direction.

10. The fastener assembly of claim **9**, wherein the ridged transverse bar includes a hook that extends from an end of the shaft, the hook having an inner surface that defines a channel that is configured to receive the second longitudinal member.

11. The fastener assembly of claim **10**, wherein the ridged transverse bar includes a set screw that extends through the hook and into the channel of the hook, wherein the set screw is configured to press the second longitudinal member against the inner surface of the hook to thereby secure the second longitudinal member to the ridged transverse bar.

12. A fastener assembly configured to affix a longitudinal member to a vertebra, the fastener assembly comprising:

a transverse bar having a shaft and a head that extends from the shaft, the shaft having a plurality of ridges and the head having an inner surface that defines a channel that is configured to receive the longitudinal member;

a fastener that includes a lower portion configured to engage the vertebra, and an upper portion that extends in an upward direction with respect to the lower portion, the upper portion having a channel that is configured to receive the shaft, the channel partially defined by a first point of the upper portion and a second point of the upper portion that is opposite the first point in the upward direction; and

an attachment member positionable on the upper portion, the attachment member including an inner surface that defines a slot, such that the slot cooperates with the channel of the fastener so as to capture the shaft when the attachment member is positioned on the upper portion, the inner surface further defining an outer section having a first center of curvature and an inner concave section having a second center of curvature that is offset inwards toward the central axis with respect to the first center of curvature, and such that the inner surface at the outer section is offset with respect to the inner surface at the inner section in the upward direction,

wherein the inner surface at the outer section of the attachment member includes a plurality of serrations configured to mate with the plurality of ridges of the captured shaft.

13. The fastener assembly of claim **12**, wherein the head of the transverse bar defines a hook.

14. The fastener assembly of claim **13**, wherein the transverse bar further includes a set screw that extends through the hook and into the channel of the transverse bar, wherein the set screw is configured to press the longitudinal member against the inner surface of the hook to thereby secure the longitudinal member to the transverse bar.

15. The fastener assembly of claim **12**, wherein the shaft is elongate along a first direction and the plurality of ridges are elongate along the first direction.

16. The fastener assembly of claim **15**, wherein the longitudinal member is elongate along a second direction that is perpendicular to the first direction, when the shaft is captured within the slot and the longitudinal member is secured to the transverse bar.

17. The fastener assembly of claim **12**, wherein the upper portion is integral with the lower portion.

18. The fastener assembly of claim **12**, wherein the channel of the upper portion is a first channel, and the upper portion further has a second channel, the first and second channels disposed on opposite sides of a central axis of the fastener.

19. The fastener assembly of claim **12**, further comprising the longitudinal member.

20. A method of fixing a longitudinal member to a vertebra with a fastener assembly, the method comprising the steps of:

affixing a lower portion of a fastener to a vertebra, the lower portion elongate along a central axis;

inserting a shaft of a transverse bar into a channel of an upper portion of the fastener, the channel partially defined by a first point of the upper portion and a second point of the upper portion spaced from the first point along a direction parallel to the central axis;

positioning an attachment member on the upper portion such that a slot that is defined by an inner surface of the attachment member faces the channel, wherein the inner surface defines an outer section having a first center of curvature and an inner concave section having a second

center of curvature that is offset with respect to the first center of curvature and cooperates with the channel to thereby capture the shaft;

fastening the attachment member to the upper portion, such that the inner surface at the inner section urges the shaft against the inner surface at the outer section, and a plurality of serrations defined by the inner surface at the outer section mate with a plurality of ridges defined by the shaft of the transverse bar; and

positioning the longitudinal member into a channel that is defined by a head of the transverse bar.

21. The method of claim **20**, wherein the fastening step further comprises the step tightening a set screw such that the set screw presses the longitudinal member against a surface that defines the channel of the head to thereby fix the longitudinal member to the transverse bar.

22. The method of claim **20**, wherein the fastener is elongate along a central axis, and the second center of curvature is offset inwardly, with respect to the first center of curvature, toward the central axis.

23. The method of claim **20**, wherein the first positioning step comprises placing the inner surface relative to the upper portion such that the inner surface is concave with respect to the slot along at least a portion of both the outer and inner sections.

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